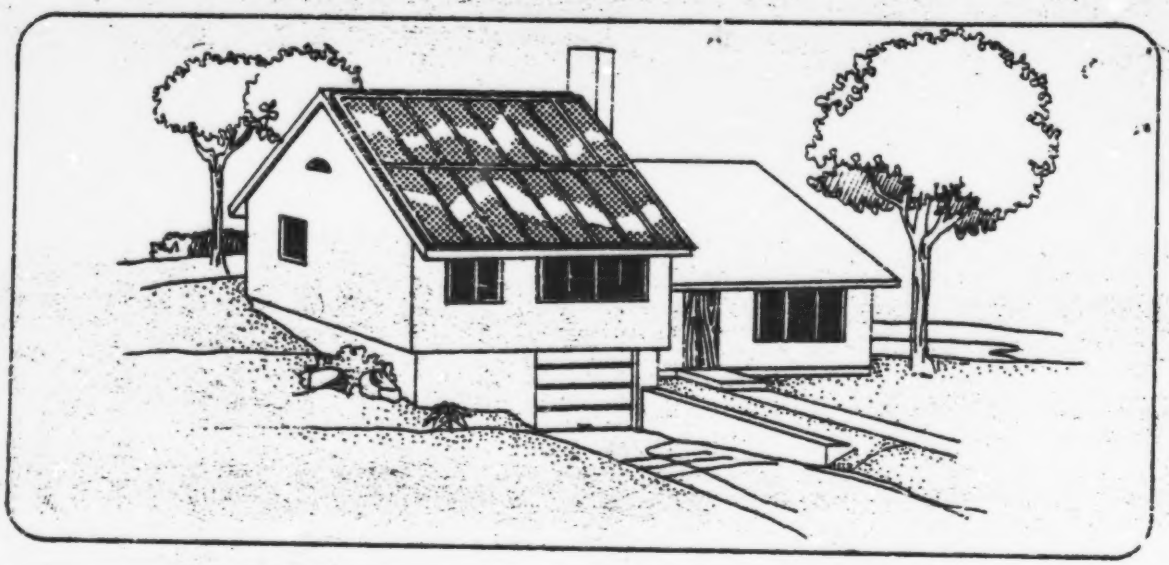
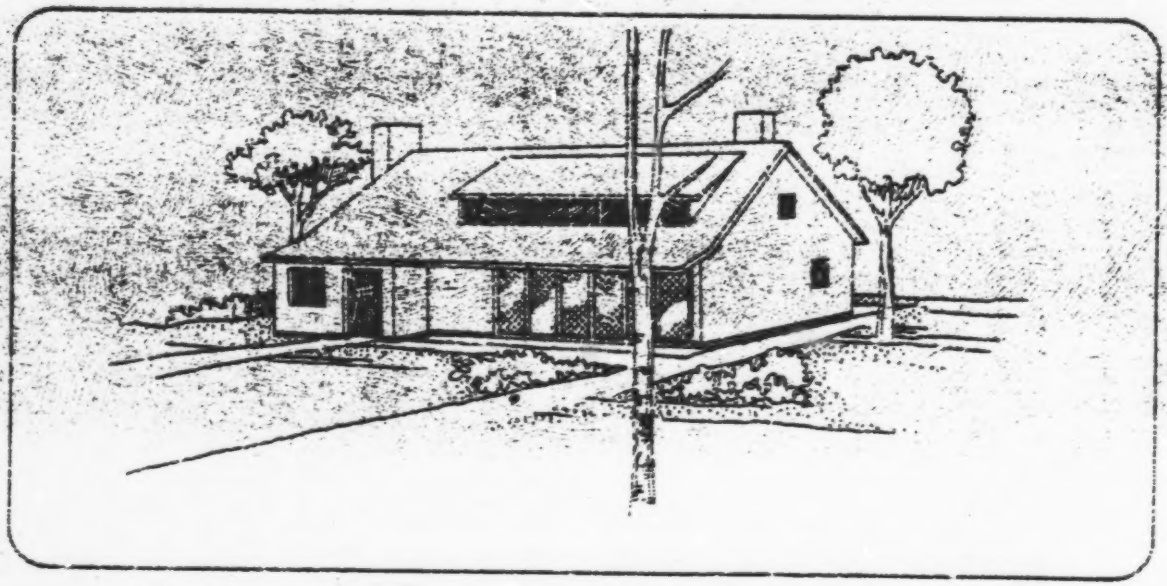


ENERGY CONSERVING LAND USE PLANNING



Edmonton Metropolitan Regional Planning Commission

October 1982

This report, prepared by the Municipal Services Division of the Edmonton Metropolitan Regional Planning Commission, attempts to inform member municipalities of the benefits of incorporating passive solar heating features into residential developments and to illustrate several potentially useful techniques to modify local subdivision practices and land use/development regulations to provide and protect solar access. The provision and protection of solar access would constitute a significant step toward reducing energy consumption in the Region.

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	LEVELS OF SOLAR ACCESS	3
III.	ORIENTATION ASPECTS	4
IV.	SEPARATION/SHADING ASPECTS	11
V.	CONCLUSIONS	20

LIST OF FIGURES

Page

FIGURE 1: Levels of Solar Access Protection..... 3

FIGURE 2: Direct Gain Passive Solar and Active Solar Systems..... 5

FIGURE 3: Duplex Orientation..... 6

FIGURE 4: Quadruplexes..... 6

FIGURE 5: Changing Quadruplex Design..... 7

FIGURE 6: Row Housing Orientation..... 7

FIGURE 7: Walk-up Apartment Orientation..... 8

FIGURE 8: Lot Orientation on Intercardinal Streets..... 9

FIGURE 9: Combining Lots for Proper Orientation..... 10

FIGURE 10: Using Flag Lots for Proper Orientation on North/South Streets..... 10

FIGURE 11: Annual Shadow Patterns..... 12

FIGURE 12: The Shade-Free Zone..... 13

FIGURE 13: Reducing Setback to Equalize Access..... 15

FIGURE 14: Reducing Setback and Increasing Lot Depth to Equalize Access.. 16

FIGURE 15: North Zero Lot Line Siting..... 17

FIGURE 16: South Building Orientation..... 17

FIGURE 17: Uniform versus Staggered Setbacks..... 18

FIGURE 18: Placement of Garages..... 19

SOURCES:

1. U.S. Department of Housing and Urban Development, Site Planning for Solar Access, Chicago; 1979 (Figures 1-10, 13, 15-18).

2. Gough, Bruce D., Passive Solar Heating in Canada, Ottawa; 1979 (Figures 11 and 12).

I. INTRODUCTION

At our Regional latitude of 53° homes require significant amounts of heat to provide a comfortable living environment for their occupants. This heat is necessary to make up the difference between heat which is lost through infiltration and transmission and heat which is gained through internal gains and solar radiation.[1]

Transmission losses through windows, walls, ceilings and floors result directly from differences between inside and outside temperatures and occur in proportion to both the resistance of the construction materials to heat transfer and to their surface area. Infiltration losses occur whenever cold air enters a heated building through cracks or whenever a door or window is opened. For both transmission and infiltration losses, temperature and wind speeds are major contributing factors.[2]

Fortunately the losses from transmission and infiltration are offset by two sources of heat gain - internal heat and solar radiation. Internal heat is associated with the operation of electrical appliances, lighting and also body heat. Solar radiation on the other hand provides heat both by penetrating windows and by warming exterior surfaces.

> "Passive solar heat gains through windows are intrinsic with the creation of any building and already contribute significantly to the heating energy requirement of buildings in Canada. Within the existing residential building stock alone, passive solar gains through windows are estimated to account for 12.5% of the gross annual residential heating requirements or the equivalent of 146.9 x 10^{15} Joules, some 2.26% of the total annual national energy consumption."[3]

Whereas low temperatures and wind in the Region present a major obstacle, the long hours of bright sunshine and the total solar insolation received in the Region offer substantial opportunities for lessening our dependence on non-renewable fuels for home heating. Recent studies show that substantial savings can result at little or no extra development costs simply by utilizing the available solar radiation by incorporating solar considerations in the design.

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1 In newer, well-designed superinsulated houses incorporating passive solar features this 'outside' heat energy demand is often less than 10 percent of a conventional house.

2 In the Edmonton Region the number of degree-days is high (10,968 days utilizing °F or 5,589 days utilizing °C) which means that significant temperature differences exist for much of the year. A degree-day accrues for every degree the average outside temperature to below 65°F (18°C) for a 24-hour period.

3 Passive Solar Heating in Canada, Bruce D. Gough, Energy, Mines and Natural Resources Canada, 1979, page 2.

> "Proper orientation of buildings toward the sun, combined with the right placement and design of windows, can save 15 to 20 percent of the energy needed in heating at no extra cost. This level of savings is possible without any special passive or active solar features, but the building orientation will also facilitate the installation of solar energy systems if and when desired."[4]

> "A modified version of true passive solar heating is the 'assisted passive system' in which solar energy is still collected by elements of the building but forced circulation is used to distribute stored heat to the best advantage. Common examples are the use of fans to distribute heat from a Trombe wall or from an air space under the roof. ...In favorable cases up to 25% of the heating load can be supplied in this way, at an additional cost of the order of $1,000 for fans, ductwork and controls."[5]

Historically little or no attention has been paid to providing homes with proper solar orientation or protecting their solar access. Low energy costs not only in Alberta but generally throughout North America has diverted our attention away from utilizing available solar energy. More recently, however, (in particular since the mid 1970's) there has been a revival of interest in solar heating as a result of: skyrocketing costs of non-renewable fuels, uncertainties associated with foreign supplies, and persistent uncertainties with respect to the development and utilization of alternative sources such as nuclear energy, and the current conservationist mood of the general public.[6] For a number of reasons this interest has been most apparent in the United States but is becoming more widespread in Canada, particularly in Eastern Canada.

Several municipalities in the Edmonton Region have acknowledged the importance of energy conservation and have included energy conservation objectives and policies in their general municipal plans relating to

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4 Regional Municipality of Ottawa - Carleton, Opportunities for Energy Conservation in Ottawa - Carleton: The Municipal Role; 1981, page 32

5 Alberta Energy and Natural Resources, Prospects for Solar and Wind Energy Utilization in Alberta, 1978, page 46

6 Since the ancient Greeks, faced with shrinking sources of firewood and lengthening supply lines, began building to capture available solar energy 2500 years ago there have been a number of periods characterized by a renewed interest in solar heating.

- It may be noted that the Edmonton Telephone Directory currently lists twelve companies under "Solar Energy Designers and Consultants' and an equal number under 'Solar Energy Equipment and Supplies'.

future residential development. Additional opportunities exist for promoting energy conservation by incorporating solar considerations into subdivision planning in order to provide solar access and by utilizing planning tools. Such as land use bylaws to protect solar access.

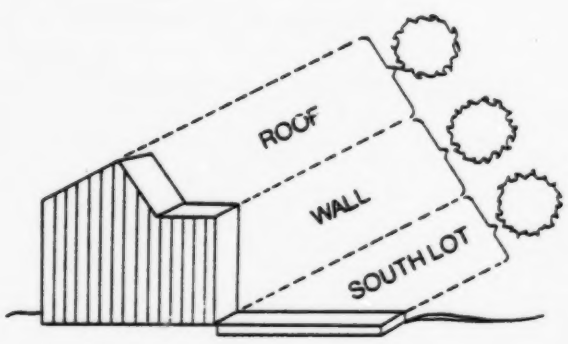
> "The opportunities for utilization of passive solar design concepts are very large, even if they are only applied to new construction and only to a moderate degree. Nearly 40,000 new housing units are built in Alberta each year, of which about half are single - and two-family homes and the remainder are apartments and row housing. In addition, large numbers of commercial and institutional buildings are constructed each year, and many of these are even more readily adaptable to passive solar design than single-family homes."[7]

Before exploring these additional opportunities however an important question needs to be addressed. What level of solar access needs to be protected?

II. LEVELS OF SOLAR ACCESS

The level of solar access needs to be established for as protection progresses from rooftop to south wall to south lot locations restrictions in adjacent lands increase (Figure 1).

FIGURE 1. Levels of Solar Access Protection



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7 Alberta Energy and Natural Resources, Loc.cit.

Throughout Alberta, south wall protection is most appropriate. This level of protection is required for "passive solar heating (which) has shown to be the one large-scale application which is almost certainly competitive now..."[8]. Consequently, the solar access planning techniques described herein reflect passive space heating requirements and serve to provide and protect south wall solar access (Figure 2).[9]

III. ORIENTATION ASPECTS

In the case of passive solar energy systems, the building's orientation is also the collector's orientation since south facing glazing is incorporated into the building itself.

There is in fact considerable tolerance in the orientation of buildings away from due south although due south, or solar noon, is the optimum direction for solar collection. "South slopes facing 15° east or west of due south receive virtually 100 percent of the radiation of a due south slope. Thirty percent off south means a loss of under ten percent. Even a south-east or south-west orientation (45 degrees from due south) will receive 75 percent of the optimum sun. With this in mind, it is easier to make the sometimes necessary compromises or alterations that local conditions may demand."[10] Further deviation from due south not only lowers winter solar reception but also progressively impairs the facility to provide overhead shading to counter increased summer solar reception.

The typical single-family detached house is separated from its neighbours and its access road by front, side and rear yards. In this situation, orientation for solar energy use is not usually a critical factor, provided that the design of the structure can be accommodated to the tolerable variation from the ideal east-west axis orientation. In other words, the building axis can swing as much as 45 degrees away from an east-west orientation.

Duplexes, two-unit structures having a common wall, ideally should be sited on an east-west axis with the common wall bisecting the structure from north to south. Should the structure be sited with both long axis and common wall north and south, then one unit will have most of its

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8 Alberta Energy and Natural Resources, op.cit., page 4.

9 This will also facilitate the rooftop installation of active solar collectors if and when desired.

10 Robert Argue, The Well-Tempered House: Energy Efficient Buildings for Cold Climates, Toronto, page 16.

FIGURE 2. Direct Gain Passive Solar and Active Solar Systems

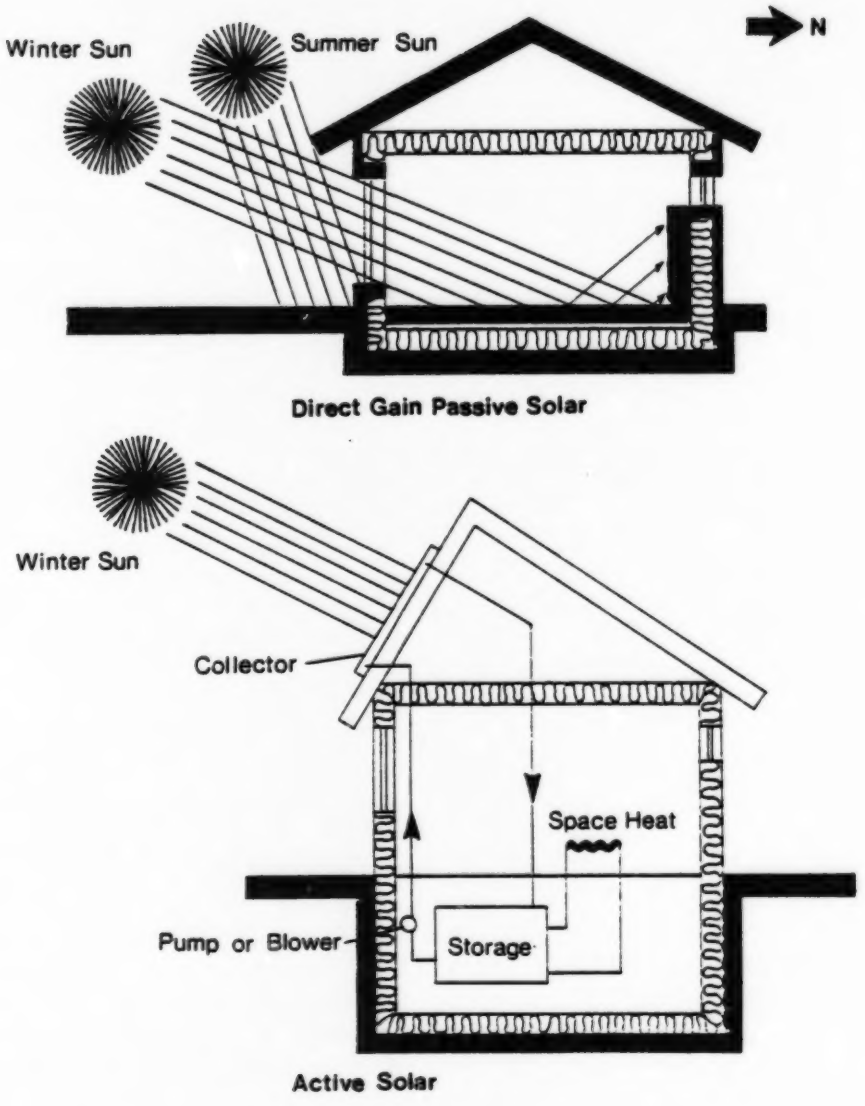
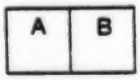
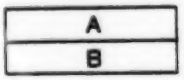


FIGURE 3. Duplex Orientation

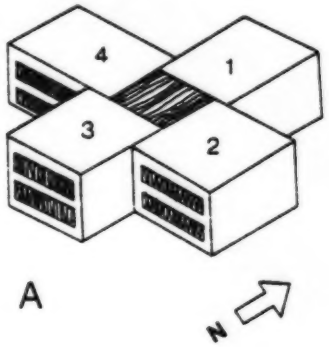
Building Axis	E/W	E/W	N/S
Common Wall Orientation	N/S	E/W	N/S
Building Shape			
Solar Access	BEST Both A & B have good access	POOR Even with sky-lights, A has less access	WORST Both have poor access and overheat

Solar access is difficult to achieve for structures containing four units although the limited access can be maximized by proper orientation. Figure 4 shows two arrangements having poor solar access. In A, Unit 3 shades Units 2 and 4, while Unit 1 completely lacks access. In B, only Units 3 and 4 have south access. The best solution would be to modify the design of the structure as in Figure 5 where all units have good access.

FIGURE 4. Quadruplexes

UNIT	SOLAR ACCESS
1	Roof/
2	Roof/ South, east wall
3	Roof/ East, south, west wall
4	Roof/ West, south wall

UNIT	SOLAR ACCESS
1	Roof/ West wall
2	Roof/ East wall
3	Roof/ East, south wall
4	Roof/ West, south wall



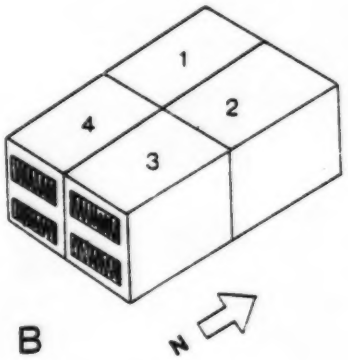
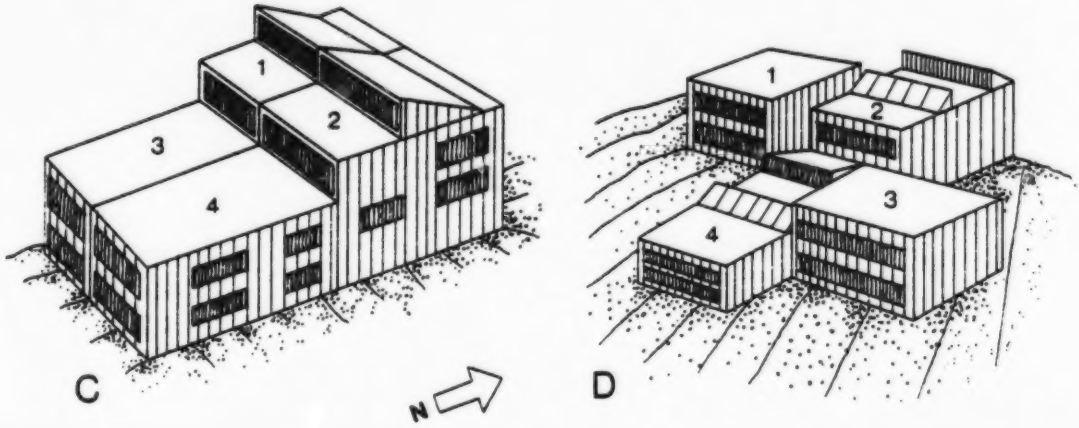
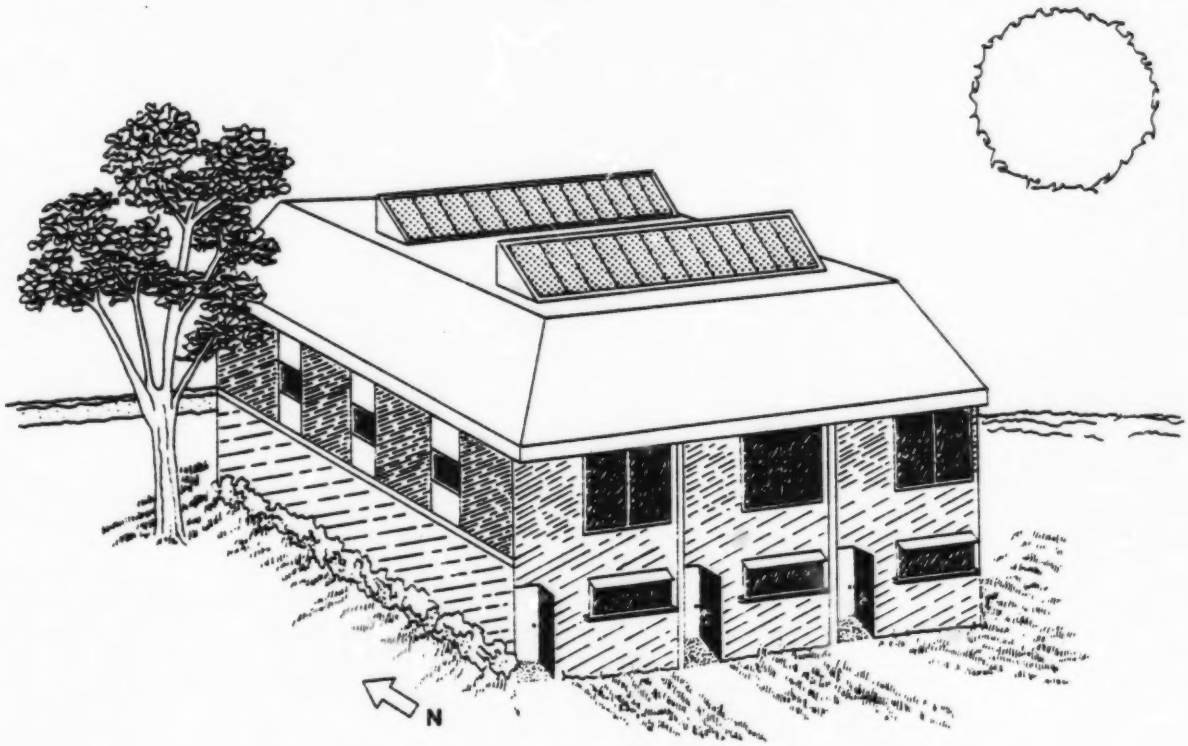


FIGURE 5. Changing Quadruplex Design



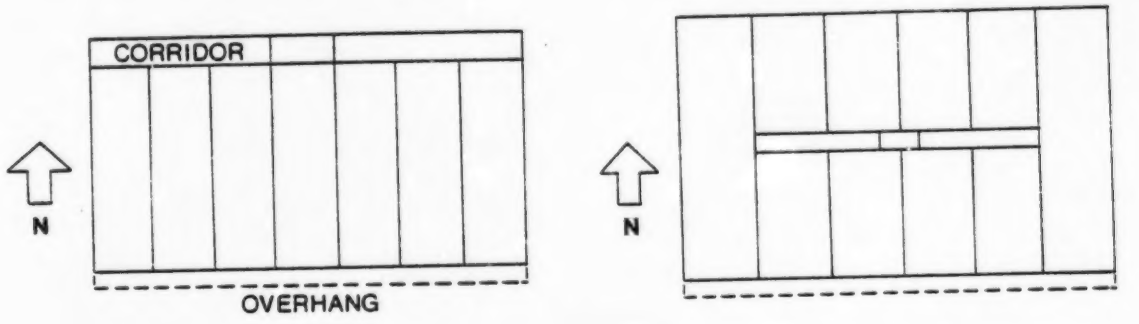
For row housing structures, individual units are best oriented with their axis north-south, with the whole structure oriented east to west. This provides each unit one wall with a south access (Figure 6).

FIGURE 6. Row Housing Orientation



For walk-up apartment structures the ideal is the single-loaded building with most of its windows facing south and the long axis running east-west. Double-loaded buildings, however sited, can expect limited solar access. An east-west alignment of individual units means probable overheating in summer, while a north-south alignment means half of the units will receive no direct sunlight during winter (Figure 7).

FIGURE 7. Walk-up Apartment Orientation



SINGLE-LOADED CORRIDOR:
ALL UNITS HAVE SOLAR ACCESS

DOUBLE-LOADED CORRIDOR:
HALF THE UNITS HAVE SOLAR ACCESS

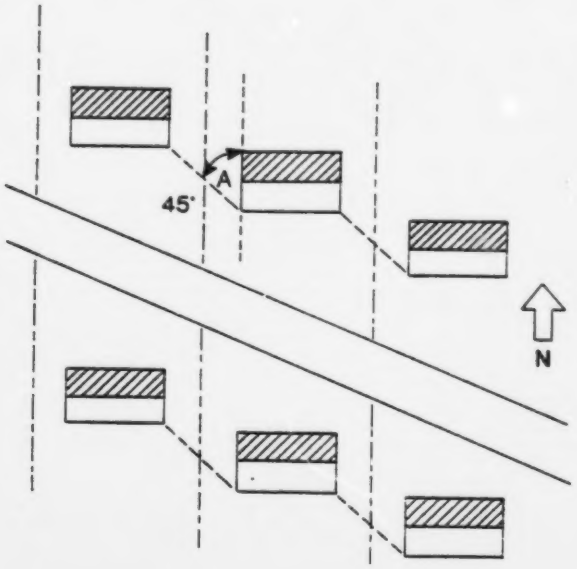
In siting buildings to meet these guidelines, a critical factor is likely to be road orientation. Because building lines follow lot lines which follow roadway alignment, building lines follow the line of the street.

One of the best ways to assure proper solar building orientation under conventional development practices is to align streets from east to west. This facilitates a southern orientation for the greatest number of buildings. Unfortunately, it is not always feasible to align streets from east to west. Topographic conditions may require that streets follow elevation contours to minimize grading costs and to prevent erosion and run-off problems. But, as previously stated, buildings still can receive adequate sunlight even if not oriented due south. For roadways, therefore, considerable variation from an east-west orientation is possible.

The corollary to an east-west street orientation is a north-south orientation of the long axis of lots. When it is impossible to align streets from east to west, lots can still be laid out so that they have proper solar orientation. If streets must run from northwest to southeast, for example, then lot lines can be laid out at oblique angles to the street (Figure 8). With the long axis of the lots running from north to south it is relatively easy to site the houses for maximum solar orientation.

Greater variation in street orientation results where lot lines are permitted to be laid out at oblique angles to the street rather than only at perpendicular angles.

FIGURE 8. Lot Orientation on Intercardinal Streets



Maintain south orientation of housing where streets are shifted from the east-west axis. Angle A is formed by the intersection of north-south with a line connecting the southwest corner of one house to the southeast corner of its western neighbour and must be 45° or greater to prevent the south walls of the houses from being shaded by their neighbours.

When streets cannot be oriented from east to west, even on a diagonal, siting buildings for proper solar orientation becomes more difficult. Two ways to maintain proper lot orientation on north-south streets are by combining lots and by using 'flag' lots. Two lots that abut each other on the north or south can be replotted; the buildings adjacent to each other in an east-west orientation provide maximum solar access as Figure 9 illustrates. The 'flag' lot technique may be used when streets are spaced far enough apart so that four lots can be run in an east-west direction, with the 'pole of the flag connecting internal lots to the street (Figure 10). Although it may result in higher utility connection costs for internal lots, it does have the advantage of creating conventional, spacing between the ends of buildings.

FIGURE 9. Combining Lots for Proper Orientation

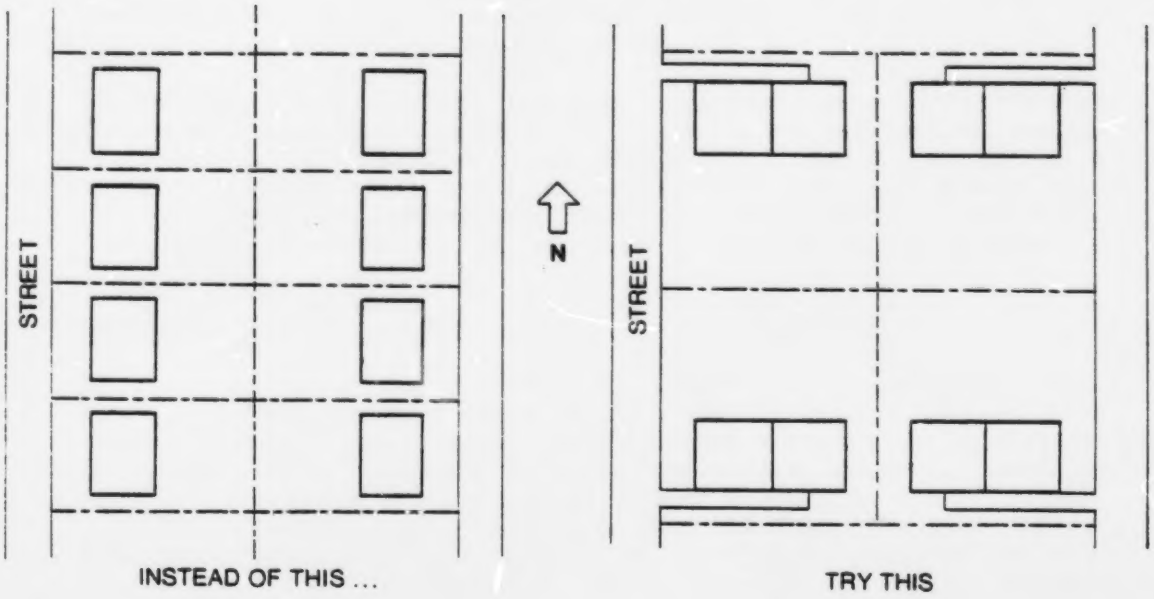
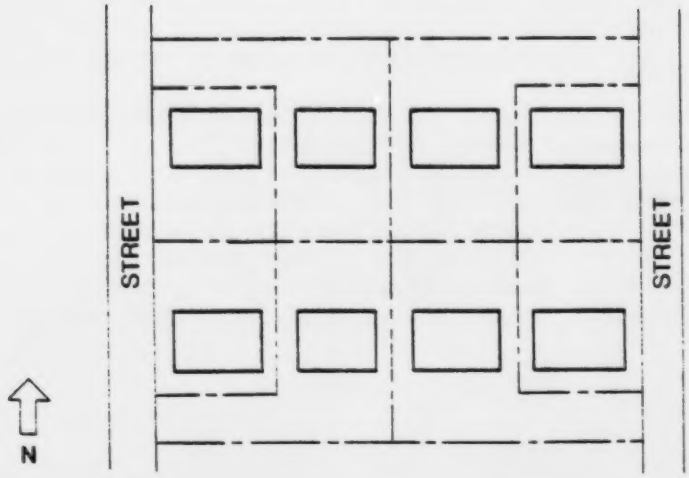


FIGURE 10. Using Flag Lots for Proper Orientation on North-South Streets



In mobile home developments, where buildings are fairly short, it is possible to have good solar access even on north-south streets. It is preferable to orient the units with their long axes east-west, offering south exposure to their largest wall and roof areas. This means that road alignments should be predominantly north-south as compared to the east-west orientation for conventional housing.

To date nearly all buildings have been built to align with their street frontages. Older street grids exhibit variable and only general cardinal orientations, while more recent subdivision practice has favored a curvilinear, cul-de-sac layout of residential streets. Consequently, many buildings lack a suitable southern wall orientation, or where this does exist, solar exposure may be shaded by other buildings or trees.

IV. SEPARATION/SHADING ASPECTS

If solar radiation cannot adequately penetrate any southward trees, other buildings, or even parts of the same building, a passive solar heating system will not work. Before siting a passive solar building (collector) it is important to define the minimum acceptable distances between the building and any shading objects in order to leave its solar collection facility largely unimpaired over the heating season. Separation requirements will be a function of the time of year, the latitude and topography of the site and the chosen level of solar access protection.

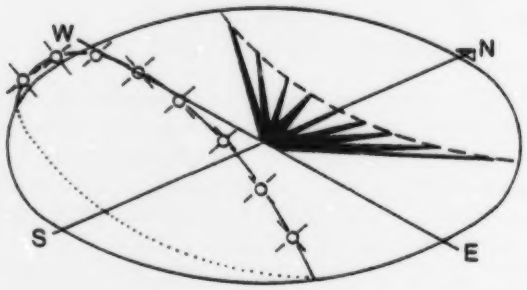
The solar shadow from an object may be readily modeled to scale using a heliodon, an instrument which simulates the geometrical relationships between the earth's surface and the sun, at any latitude and time of year. Otherwise the shadow length and direction may be calculated directly from solar altitude and azimuth angles.

As the sun rises objects will cast a westward shadow of infinite length which gradually shortens as the sun rises until solar noon at which time the shadow lies due north and is of minimum length for the day. Thereafter, the shadow length increases and moves eastwardly until the sun sets and the shadow is again of infinite length.

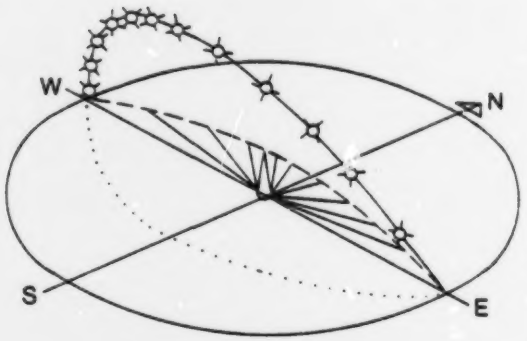
As the earth's declination to the sun increases from winter to summer both the altitude and the azimuthal movement become greater. At the winter solstice the daily shadow pattern of an object at Edmonton's latitude is boomerang-shaped, its sunrise and sunset arms trailing approximately northwest and northeast respectively (Figure 11). At the equinox, the sunrise and sunset arms fall due west and east respectively. At the summer solstice the shadow pattern is again boomerang-shaped but the sunrise and sunset arms fall southwest and southeast respectively.

FIGURE 11. Annual Shadow Patterns

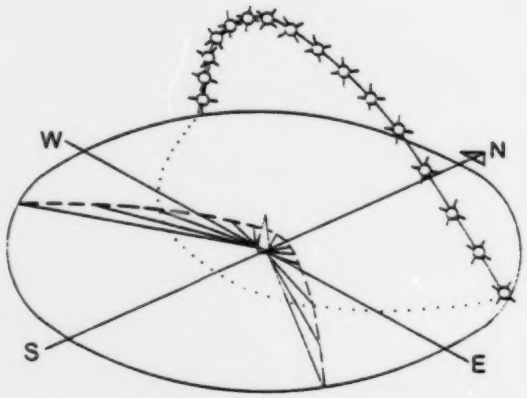
WINTER



EQUINOX



SUMMER

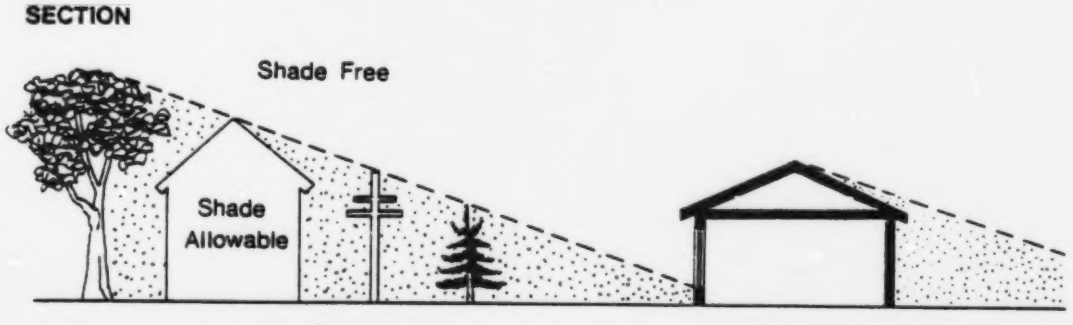


As the earth's declination varies from +23.45° on the summer solstice to -23.45° on the winter solstice, then clearly, both the lowest solar altitudes and longest northward shadows occur on December 21st. This date, near the middle of the heating season, is the logical date for determining shadow-free southward exposure. Due to increased solar altitude at other times, and the subsequent recession of shadows from southward objects, any solar exposure upon a south-facing surface on December 21st is assured for the remainder of the year.

It is not reasonable however to prevent shading upon a south wall over the entire day on December 21st as shadows are of infinite length near sunrise and sunset. Nor is it necessary. The sun if of low intensity at these times and furthermore large solar azimuthal angles from due south in early morning or late afternoon make the solar incidence angle high and solar intensity low upon a south facing surface. Since the solar transmittance of most glazing materials declines rapidly beyond incidence angle of 45° and because the quantity of solar radiation received upon a surface declines rapidly when the receiving surface is oriented more than 45° from due south, it is acceptable to limit both the lateral shade-free area and the bearing of a collector/window to with $\pm$ 45° of true south.

These solar azimuthal and altitudinal considerations define a cone-shaped, minimum shade-free zone which must exist to the south of a passive solar collecting surface (Figure 12).

FIGURE 12. The Shade-Free Zone



SHADOW LENGTH = SHADING OBJECT HEIGHT ÷ tan (SOLAR ALTITUDE)

On December 21st, any object which penetrates the plane of the solar altitude extending from the base of a south facing wall and within + 45° of due south violates the shade-free zone. A shadow from an object located + 45° south of the building creates no problem provided it lies beneath the plane of the solar altitude.

Since the shadow length from an object is a function of its height times the cotangent of the solar altitude angle then the closest a shade producing object may approach a south facing passive solar wall depends upon its height. The northward shadow project cast by an object at Edmonton's latitude is 4.1 units per limit object height.[11] In the Edmonton area this means that a 10 meter tall object should not come within 41 meters of the axis of a due south facing wall. As the receiving surface orientation is moved from due south, the minimum normal distance from the axis of the south wall to the object increases as a function of the sum of the sine plus cosine of the receiving surface azimuth angle from due south. These shade-free zones are general and will be moderated by the fact that shadow lengths vary on sloped sites. On south slopes they are shorter making possible a closer spacing of buildings and on north slopes they are longer necessitating a wider spacing of buildings.

Where buildings are sited in the traditional way with front, side, and rear yards some buildings may have better solar access than others. As Figure 13A shows the rear yards of buildings sited on east-west streets may be relatively small. As a result, the distance between houses that back onto each other being 190.5 m (75 feet) is less than the distance between those that face each other. Consequently, houses on the south side of the street are shaded.

Depending on latitude and topography, adequate solar access may be provided under standard setback requirements by means of a simple adjustment. By reducing the frontyard setback and increasing the rearyard setback, the distance between houses that back onto each other and houses that face each other can be made nearly equal. In effect, this moves all the structures closer to the street and improves solar access to the houses on the south side of the street (Figure 13B).

The setback requirements for an R-2M (Medium Density) district in the town of Redwater are illustrated in Figure 14A. Clearly this kind of simple adjustment would not serve to improve solar access. In order to improve solar access in this instance lot depths would have to be increased from 304.8 m (120 feet) to 337.8 m (133 feet) and the front yard setback would have to be reduced from 122.8 m (46 feet) to 92.7 m (36.5 feet)[Figure 14B].

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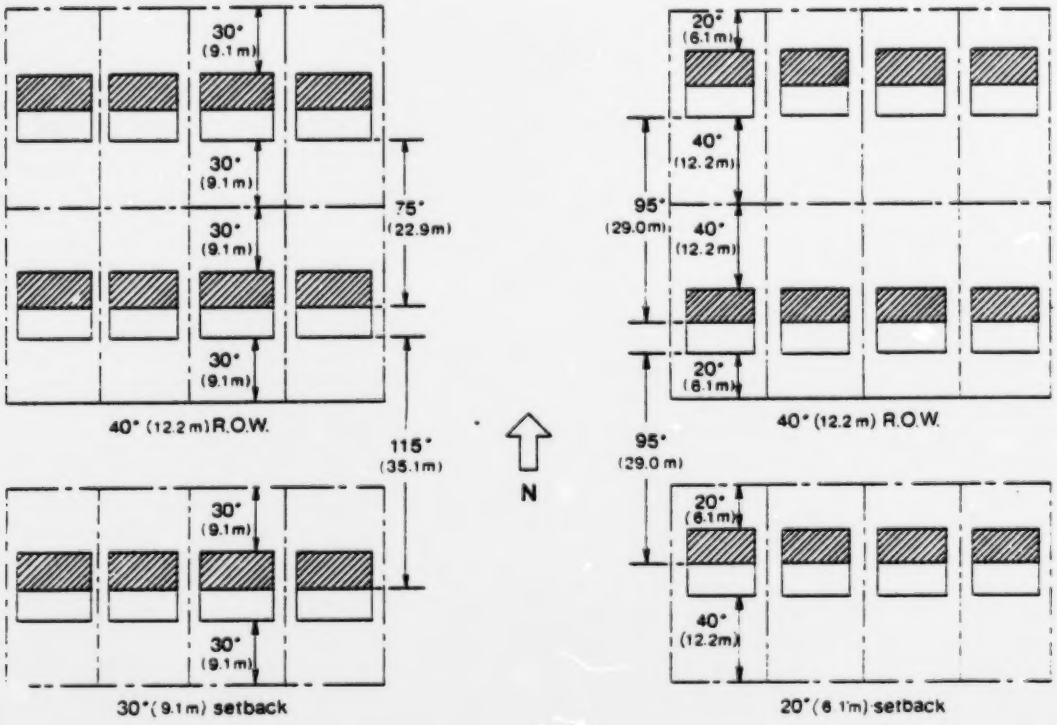
11 Bruce D. Gough, op.cit. page 54.

FIGURE 13. Reducing Setback to Equalize Access

A. Traditional Setback and Unequal Access

B. Reducing Setback and Equalize Access



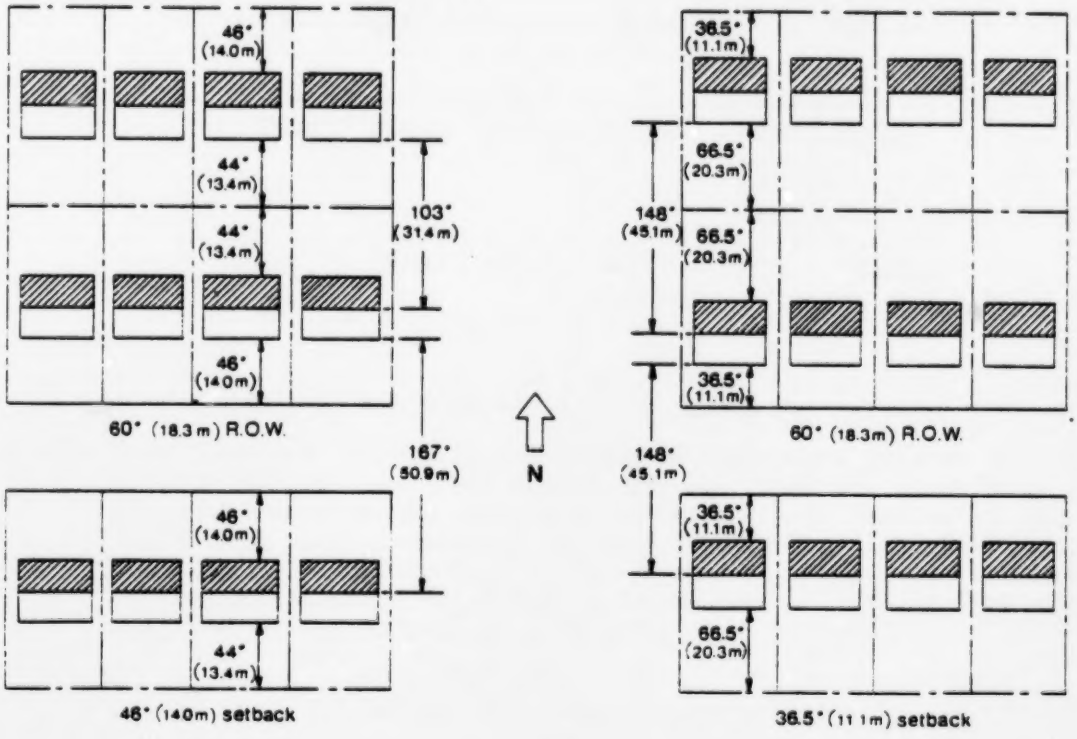
Hypothetical site, flat at 40°N. latitude, with a shadow projection of 87.5 ft. for 25 ft. high buildings.

In A, only buildings to the north of road right-of-way have south-wall access. By reducing setback by 10 ft. [from 76.2 m (30 ft.) to 50.8 m (20 ft.)], all structures have south-wall access in B. This affects shading only by buildings; street trees must be regulated to prevent shading problems.

FIGURE 14. Reducing Setback and Increasing Lot Depth to Equalize Access

A. Traditional Setback and Unequal Access (R-2M)

B. Reducing Setback and Increasing Lot Depth to Equalize Access

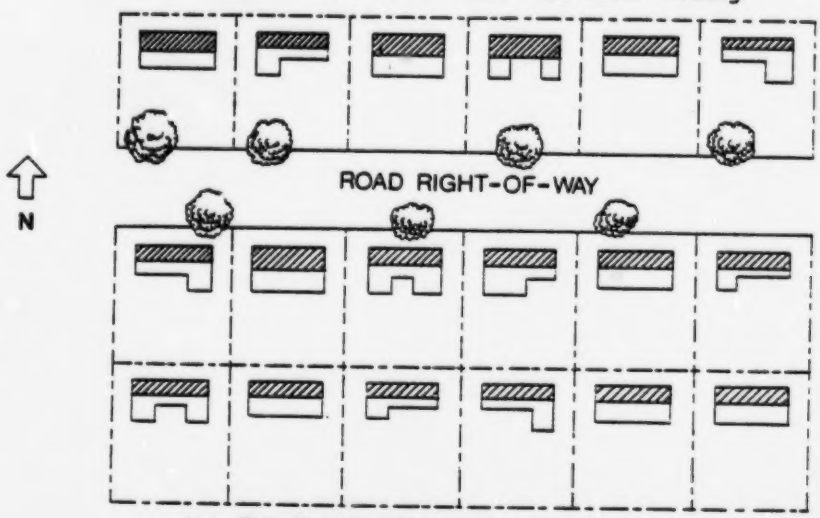


Hypothetical site, flat at 53°N. latitude, with a shadow projection of 147.6 ft. for 36 ft. high buildings.

In A, only buildings to the north of road right-of-way have south-wall access. By reducing setback by 24.1 m (9.5 ft.) [from 122.8 m (46 ft.) to 92.7 m (36.5 ft.)] and increasing lot depth from 120 ft. to 133 ft., all structures have southwall access in B. This affects shading only by buildings; street trees must be regulated to prevent shading problems.

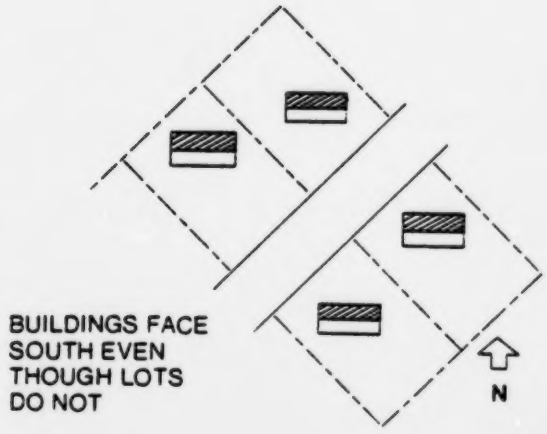
One approach that is useful for protecting solar access is a variation of zero lot line siting. For solar access, allowing buildings to abut the north lot line provides the largest possible yard area to the south of each building (Figure 15).

FIGURE 15. North Zero Lot Line Siting



This technique is equally applicable to houses and lots on north-south streets if lots are large enough and buildings are sited with their sides to the street for optimum solar orientation. Applied to lots on a street that runs diagonally, the provisions would allow for siting the building in the northernmost corner of the lot as Figure 16 illustrates. In this situation, there may still be substantial shading from adjacent buildings in the morning and afternoon.

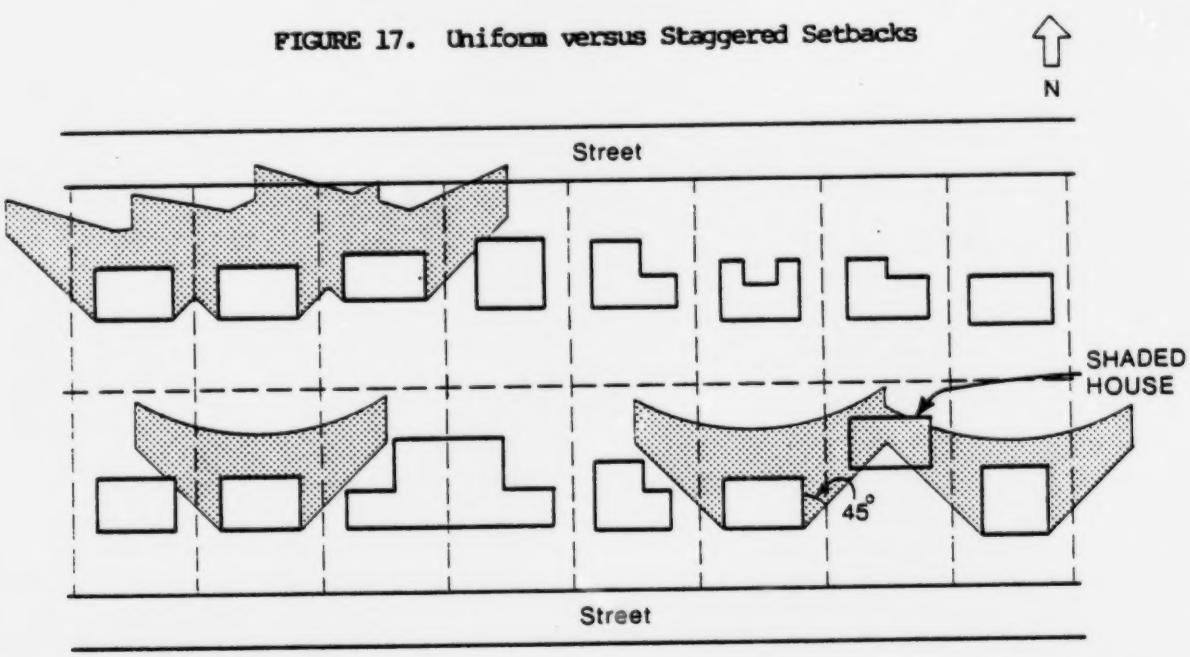
FIGURE 16. South Building-Orientation



The application of this technique can significantly alter the design of residential neighbourhoods. Houses to the south of an east-west street would front the road while buildings to the north would be set back a greater distance resulting in an unusual massing of structures. Secondly, utility connections might be more expensive for lots on the north side of the street although savings for utility hookups to houses on the south may balance this off. Finally, moving houses so close to the street may limit the occupants' privacy although privacy may be protected by putting in fences or landscaping.

Under existing setback requirements, houses may be staggered as long as they meet minimum and not exceed maximum yard requirements. This can pose shading problems in the morning or afternoon. Uniform building setback, on the other hand, protects solar access. Figure 17 illustrates the solar access benefits of uniform setbacks over staggered setback.

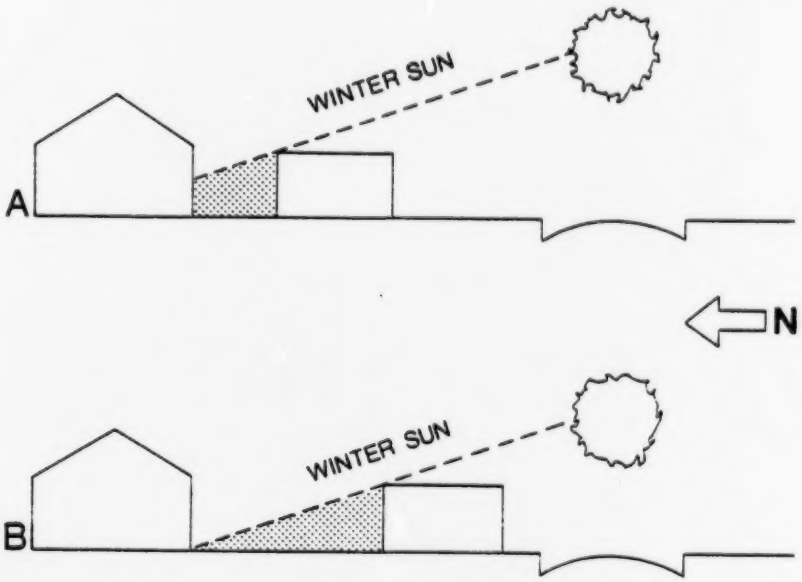
FIGURE 17. Uniform versus Staggered Setbacks



Reducing the frontage of lots on east-west streets is another way to improve solar access. Holding lot size constant while reducing frontage results in narrower but deeper lots with more distance between buildings from north to south. In the case of the solar access problems associated with the R-2M (Medium Density) district in Redwater reducing lot frontage from 175.3 m (69 ft.) to 158.2 m (62.3 ft.) would result in the required 337.8 m (133 ft.) lot depth while keeping lot size constant. Obviously, this technique means a reduction of sideyard space and gives a development a more clustered look.

Garages, fences and other accessory structures must be sited so that they do not shade south walls of buildings requiring solar access. Accessory buildings can be sited to the north of the main building whenever possible provided that they do not cause a problem on adjacent, northerly property. When garages or fences are sited to the south, they must be set far enough back from the main building that their shadows do not encroach on the building's south wall. Siting them as close as possible to the southern property line is desirable for this reason (Figure 18).

FIGURE 18. Placement of Garages



V. CONCLUSIONS

At this present time this province's subdivision regulations contain no provisions for encouraging proper solar orientation. Consequently new types of street and/or lot orientation regulations would have to be considered by communities wishing to provide solar access taking into account proper road, lot and building orientations within the proposed development. For example, Sacramento County in California, by requiring all lots in new residential development to be oriented within 22.5 degrees from south, promotes the proper east-west road (and building) orientation.

Moreover, existing land use bylaws do not adequately deal with the separation/shading aspects of solar access. Since height and setback of buildings determines how much they shade each other land use bylaws could provide direct and established control. Specifically, there may be five ways for modifying existing land use bylaws in order to protect solar access. They include:

(1) reducing maximum allowable building height;

(2) reducing minimum frontage requirements for lots on east-west streets so that lots are deeper;

(3) decreasing sideyard requirements and increasing front and rearyard requirements for lots on east-west streets;

(4) using zero lot line techniques to increase the size of the south lot area under the control of the owner; and/or,

(5) using bulk plane provisions in lieu of straight height restrictions to regulate building height.

With respect to dealing with the separation/shading aspects of solar access it should be pointed out again however that although the shadow projection technique described herein provides a rough guideline for separation requirements more sophisticated but time-consuming techniques would have to be employed in order to take into account variations in local site factors, in particular local topographic, or slope, conditions.

Finally, the determination of urban land use patterns is already a complicated process involving an extensive network of approval authorities, and building codes and bylaws relating to land subdivision, road layout, drainage, servicing, building setbacks, building height and so forth. Some of these practices may not easily yield to the techniques of solar planning, particularly where the requirement of solar exposure, by limiting the maximum height of buildings and/or the minimum space between buildings, may limit the number of residential units or total building area a developer may build upon a parcel of land. As yet it has not been determined whether and to what degree solar exposure acts

as a constraint upon unit coverage densities. The fact remains however that if the implementation of passive solar technologies is ever to become widespread in the Edmonton Region, it will be necessary to extend existing conventional subdivision planning and land use districting criteria to include solar access considerations in the design and development of building patterns.

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